Review

This paper presents a novel LES code for simulating atmospheric boundary layers and convection, focusing on three main points:

- **Thermodynamic Potentials Approach:** The code achieves thermodynamic consistency by deriving all relevant quantities from thermodynamic potentials, such as internal energy. This approach, while intricate, provides a robust framework for moist thermodynamics.
- **Semi-Implicit Semi-Lagrangian Numerics:** Departing from traditional LES models, the code employs numerical methods more commonly used in global models. This allows for larger time steps and more efficient simulations, particularly for sub-kilometer resolution cases.
- **Implicit LES:** Instead of explicit subgrid turbulence models, the code leverages dissipation from its numerical methods to represent small-scale effects. While effective, this approach exposes certain limitations near surface boundaries.

The paper also emphasizes the accessibility of the code for both research and practical applications. Features such as predefined test cases, built-in diagnostics, minimal setup requirements, and compatibility with modest computational resources enhance its usability.

Results from standard test cases demonstrate competitive performance compared to traditional LES models. However, areas for improvement are identified, particularly regarding near-surface behavior and sensitivity to numerical configurations.

The paper is exceptionally well-written and highly comprehensible, providing nearly all the details required for reproducibility.

Comment

The code in its current state cannot be used to run highly accurate simulations, as it is parallelized only with OpenMP shared memory parallel capability. Parallelization with MPI or, even better, MPI:GPU could significantly enhance the usability and scalability of the solver. I have tested the solver on my machine and obtained the same results as those displayed in the paper. I am therefore confident that this solver, along with all the explanations provided, will be highly beneficial for the community.

Questions

General comparisons

- Adding a small subsection that highlights a comparison with existing literature could further contextualize the code's performance and its advantages or limitations relative to established models.

Stability

- The author claims stability for large acoustic, gravity-wave, and advective Courant numbers, with examples provided in test cases (e.g., ARM and DYCOMS).
  - How generalizable are these stability claims? Can similar stability be achieved for cases with stronger turbulence or more complex boundary conditions, such as heterogeneous surfaces or strong temperature gradients?
  - Are there scenarios where the acoustic or advective Courant numbers exceed the reported values, leading to instability? Could the author clarify the specific limits for stability compared to other methods?
  - While the model reportedly handles advective Courant numbers > 1, what measures ensure numerical accuracy at these high values? For instance, how do errors in interpolation or advection affect the resolved structures?

Timestep limitations

- The author notes model failure when time steps are increased beyond 6 seconds in the DYCOMS case.
  - Is this limitation consistent across all cases, or does it vary depending on physical parameters (e.g., turbulence intensity, stratification, or domain resolution)?
  - Was a systematic sensitivity analysis performed to determine the optimal timestep for different types of flows? How does timestep selection affect both stability and computational cost?

Semi-Lagrangian accuracy

- The accuracy of semi-Lagrangian trajectory calculations decreases as eigenvalues of $\Delta t \nabla u$ approach/exceed 1.
  - Could the author quantifies the impact of these inaccuracies on key diagnostics, such as turbulent kinetic energy or scalar variance, particularly in regions where vertical shear is strongest?

Comparisons with explicit solvers

- The semi-Lagrangian formulation is noted for enabling large timesteps compared to explicit schemes.
  - Could the author provide direct comparisons (e.g., runtime, accuracy, or computational cost) between their method and traditional LES solvers under similar setups?

  - How does the semi-implicit scheme affect the resolution of fast dynamical processes, such as wave breaking or sharp density gradients, compared to explicit solvers?

Deformational Courant number

- The deformational Courant number is mentioned as a potential limiting factor for stability, especially in regions with strong vertical shear.
  - How frequently does the model approach the instability threshold in practical simulations, such as those with strong surface shear or boundary-layer phenomena?
  - Are there any mitigation strategies (e.g., adaptive timestep control or trajectory smoothing) to manage cases where the deformational Courant number approaches or exceeds 1?